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EARLY HISTORY OF THE FREMANTLE GRAVING DOCK.

(BY W. H. SHIELDS).

The author admits, while he may appear to claim certain designs, that any great conception to be highly successful must bear the stamp of many minds. A departmental work has in this direction possibilities upon which the private practitioner must always cast envious eyes, and on the work of the Fremantle Graving Dock all these sources have been availed of to the fullest extent. In this direction not only was the history, procedure and methods of construction, together with the resulting success or failure, both physically and commercially, of every dock ever constructed whereof a record could be found, carefully investigated, weighed and appropriated where thought advisable ; but the author was able to draw upon the hearty and sympathetic co-operation of his colleagues in the departments, besides the advice and help of those at the time responsible, namely, the late Mr. C. Y. O'Connor, his successor (Mr. Palmer), and the present Engineer-in-Chief, Mr. Thompson ; also the late Engineer for Harbors and Rivers, Mr. Dillon Bell.

Besides all these there was advice from such English experts as Messrs. Coode, Son & Matthews, and besides their written words on the subject the author had the privilege of being closeted for days with Mr. Napier Bell and with Sir Whately Eliot, during which time practically every detail of the work and methods of construction were discussed.

To Mr. Turnbull, who when the dock became a burning question in 1907 was specially named to carry out the designs in conjunction with the author, is due many a suggestion the result of much painstaking research.

The co-lateral branches were also undertaken by experts. When it came to the question of workshops, machinery, cranes, etc., besides having the written literature on the subject, Mr. Leslie (Past-President of this Institution) lent his valuable assistance and experience, to which Mr. Hume, the Chief Mechanical Engineer of the Railway Department, not only added his knowledge, experience and practical help, but became practically responsible for that part of the work as embodied in plans drawn up by Mr. Higgins.

In like manner the Government Electrician spent his time and talents on the electrical portions, such as cranes, capstans, lighting, pumping, etc., etc. ; while several of the best-known pump makers put in specifications for the pumps and pumping plant, accompanied by sketch plans showing the space required, etc.

All this is much as it should be and must give splendid results from a Government point of view ; but it has the defect that the individual becomes merged in the department, and in a certain measure loses his individuality.

Perhaps some day this difficulty may be overcome, so that the praise or blame will be distributed to all taking part in a design proportionately to their share therein.

Sir Whately Eliot also most generously gave his services voluntarily and without charge for the benefit of this State by keeping up a correspondence with and inviting the author to freely consult him on all sorts of proposals *re* the dock, both general and detail. Mr. Wentworth Shields, Engineer for Southampton, also freely rendered service, as did Mr. Waddel, Engineer at Barry, Mr. Thompson, Engineer of the U.S. Navy Yard, Boston, Mass., and others.

From the time the author took charge of the work in 1898 until he surrendered if about three years ago, the author always had the most intimate and friendly relations with the Engineer-in-Chief, Mr. Thompson; whereby the work was much facilitated, red tape being altogether avoided.

My thanks are due to the Public Works Department for the loan of plans, and to Messrs. Ruskin for photographing them at very short notice.

In considering a dock for any port, the first consideration is—Does the trade of the port warrant its construction ? And in this light, if Fremantle be compared with other ports the answer cannot be otherwise than favourable.

In the following table many of the ports are only a few miles from other ports with docks. Fremantle is absolutely isolated. (These figures are taken from the official files and are several years old, witn the exception of Fremantle, which is taken from the newspaper account of the latest report).

Southampton, 3,800,000 tons of shipping ..	5 docks over 350 ft. long. 2 docks under 350 ft. long. 5 slips. 5 gridirons.

On this basis, Fremantle should have at least 13 docks and slips.

Newport, 2,700,000 tons	5 docks over 350 ft. long. 2 docks under 350 ft. long. 1 gridiron.

Swansea, 2,500,000 tons	4 docks over 350 ft. long. 5 docks under 350 ft. long. 1 gridiron.
Manchester, 2,000,000 tons	1 dry dock over 350 ft. long. 2 floating docks. Other docks quite near.
Glasgow, 4,300,000 tons	5 docks over 350 ft. long. 3 slips.
Leith, 2,000,000 tons	1 dock over 350 ft. long. 6 docks under 350 ft. long.
London, 19,100,000 tons	13 graving docks over 350 ft. long. 2 of them 846 ft. long. 15 dry docks under 350 ft. long. 3 slips.
Liverpool, 19,500,000 tons	15 dry docks over 350 ft. long 4 of which are over 900 ft. 7 docks under 350 ft. long. 1 slip. 2 gridirons. There are other docks close by.
Cardiff, 13,200,000 tons	9 docks over 350 ft. on floor. 4 docks under 350 ft. on floor. 2 floating docks. 2 slips. 2 gridirons.
Newcastle, including North and South Shields, 9,000,000 tons	10 docks over 350 ft. long. 12 docks under 350 ft. long. 8 floating docks. 15 slipways. 1 gridiron.
Hull, 4,700,000 tons	3 graving docks over 350 ft. long. 6 graving docks under 350 ft. long. 7 slips.
Grimsby, 1,700,000 tons	3 docks over 350 ft. long. 1 pontoon dock. 1 slip.

Melbourne, 6,500,000 tons	2 docks over 350 ft. long. 1 dock under 350 ft. long. 5 slipways.
Sydney, 5,900,000 tons	4 docks over 350 ft. long. 4 floating docks. 3 slips.

Mr. C. S. Palmer in his report of December 1st, 1904, points out that it is usual in the United Kingdom to provide one dock for every 180,000 tons calling at the port.

From the figures in the above table, it will be evident that were there other docks as close to Fremantle as Claremont, Perth or Rockingham, the Port would be quite justified in having as many as a dozen docks, whereas it has none.

How long can the traders and public of Western Australia afford to pay higher freights and insurance fees between Western Australia and Europe than those charged from Melbourne or Sydney to Europe? Because such must always be the case where it is impossible to effect repairs to a ship's hull locally.

Shortly after the opening of the bar had been started at Fremantle, the question of a graving dock was brought up by Mr. O'Connor asking the then resident engineer, Mr. Dillon Bell, to report on a site. About the end of 1894 Mr. Bell suggested building a wooden dock of jarrah, similar to some that had been built in the United States for about half the cost of stone docks. He proposed a site at Rous Head, the dock running straight in to the bank at about right-angles to the stream, the size proposed being 600 ft. by 100 ft.

In many old wet docks where land and wharfage were exceedingly valuable the dry docks were placed so as to occupy the least possible amount of wharf and were therefore put end on or facing a corner, the still water of the wet dock allowing the ships, which were then small, to enter in almost any direction. At that time in Fremantle land and frontages were of little value, while the rapidly growing size of ships, and the river currents, made it practically prohibitive for a ship to lie athwart the stream when entering a dock.

The proposal to build a timber dock, on the precedent of some built in the United States, where timber had only been used as a solid lining to a clay hole, without any necessity to make it water-tight, the entrance, of course, being of concrete was fallacious.

Fortunately, these two fallacies were foreseen by the then Engineer-in-Chief.

The English consulting engineers, Messrs. Coode, Son & Matthews, also agreed as to the unsuitability of timber for even a small dock in porous strata, such as exist at Fremantle.

It is probably now well known that wood-lined docks did not prove a success even where the strata were suitable, one having been burned and one or two collapsed, while the maintenance was so enormous that the timber was replaced by masonry.

The following information, gleaned from the *Scientific American*, is instructive :—

Cost of maintaining three stone docks from 1892 to 1899	\$4,543
Cost of maintaining three wooden docks from 1892 to 1899....	\$426,073

Besides \$600,000 spent on reconstructing that at Brooklyn.—

Scientific American, Oct. 20th, 1900.

Floating docks were at this time (early in 1895) also considered, but the idea was not very favorably received by the English consulting engineers on account of the difficulty of docking, painting, cleaning, and repairing the floating dock.

In July, 1895, Mr. O'Connor, when instructing Mr. Dillon Bell to have borings made over the proposed dock and slip site, after discussing the necessity for both, states, *inter alia* :—

"Will you, therefore, please have borings made accordingly on the area of the proposed reclamation near Rous Head . . . . . being probably the most convenient, and it seems to me that convenience of situation is almost the only point to be studied, as there is, I fancy, very little advantage as regards probable cost in any one site over any other."

The bores were put down under the charge of Mr. Frank Reed, and proved the rock near Rous Head to be what is known as a "coralline rag" interbedded with beds of seaweed and sand, with occasional small lenticular beds of clay, the whole being about as watertight as a good sponge.

Captain Russell, R.N., at that time harbor master at Fremantle (August, 1895), pointed out, as had already been done by Mr. O'Connor, that the slip and dock should be alongside of each other, and he (Capt. Russell) would prefer them nearly parallel to the root of the North Mole.

In July, 1896, Mr. Napier Bell entered upon his task of designing a graving dock for Fremantle.

About this time bores were completed at a site on the north side of the river just west of the Railway Bridge. These proved the strata to be sand for a depth of 100 feet below L.W.M., and where the sand was passed through it was found to be underlaid by mud. Mr. McDonald

who put down the bores, considered further borings a waste of money as he did not think a dock could be built there other than a wooden dock.

Mr. Napier Bell completed his plans, specification and report about the end of December, 1896.

The following extract is from Mr. Napier Bell's report :—

"The best site is on the south side just above the railway bridge. Here a dock might have been built on the solid limestone, and a deep channel dredged into your intended channel in the inner harbor ; but I presume that the bridge and the interests connected with the railway in its present position put this site out of the question.

"The site on the north side of the river near and below the railway bridge is sand for about 100 feet. . . . . There is ample room for all purposes and that is about all there is to recommend it. . . . . . I think it is likely that much trouble, expense and risk would be incurred in getting foundations on running sand under 38 feet of water. . . . . The *pumps would draw quantities of sand* with the pumped water. Such a state of things usually gives great trouble, causing the work to be undermined by the pumping necessary to keep the foundations dry during construction. This, although *sand is a good foundation if it is quiet and undisturbed*, great delay and cost might have to be incurred to get the foundations successfully laid, although if once that were done, no doubt the dock once made all would be right afterwards. . . . . . The site at Rous Head has also its defects, but I don't think they are so serious as might be met with at the bridge site.

"The defects are uncertainty of the strata, layers of sand and soft stone being intermixed and irregular, but as far as can be ascertained the foundations will all come on good hard limestone."

The dimensions of this design were as follows :—Length, 560 with caison on inner stop, 590 with caison on outer stop ; width of entrance, 80 ; depth on sill, 28.

In June, 1897, the Admiralty were approached for a subsidy, and in July Mr. Coode was asked to advise as to pumps ; while in the same month Messrs. Clark and Stanfield forwarded plans for a self-propelling floating dock capable of lifting a second-class cruiser.

The question of a floating dock had been a matter under discussion early in 1895, but had not at that time been favorably entertained by the Consulting Engineers. Messrs. J. W. Henderson and Captain Laurie had also in 1895 offered the Government an option over a second-hand floating dock then lying in Sydney Harbor.

Messrs. Coode, Son & Matthews advised the use of three 33-inch pumps with disks 6 ft. 6 in. in diameter of 165 revolutions per minute, capable of emptying the dock designed by Mr. Napier Bell, and containing

12,000,000 gallons, in four hours, the drainage pump to have a 4 ft. disk. each pump to be driven by one cylinder 20 in. diameter, 22 in. stroke, using steam at 100 lb. pressure per sq. in., furnished by three boilers 7 ft. 6 in. diameter, 30 ft. long, a 5 ft. boiler 20 ft. long serving for the drainage pump.

A discussion followed as to the advisability of using triple-expansion engines, but Messrs. Coode, Son & Matthews considered that the extra cost and complicity of triple-expansion engines did not warrant their use for a pumping plant running so intermittently as the pumping plant of a dock.

In November, 1897, the Lords Commissioners of the Admiralty expressed their thanks for the opportunity they had been given for considering the matter, but regretted that in view of the many serious expenses they had to meet at the present time they were unable to make a grant towards the undertaking. They were also of the opinion that a mercantile dock would probably meet all present naval requirements.

About the same time Mr. O'Connor wrote to Mr. Napier Bell a description of a method he had seen employed to construct a large dock at Glasgow, where the foundations were in very porous materials. He asks Mr. Napier Bell if he knows of or considers there is any special feature at Fremantle that would preclude the adoption of similar tactics with equally marked success for the site in sand near the upper end of the harbor. Mr. O'Connor pointed out that the evidence discovered at Fremantle points to a successful issue.

Briefly, the method employed was to—

1st. Dredge out the site ;

2nd. Lay concrete under water to form a light outer shell ;

3rd. Pump in sand and gravel, to lend stability ;

4th. Excavate in the sand and gravel filling a narrow strip across the dock, and after caulking the leaks in that strip to complete in the dry that strip of the dock ;

5th. Complete the dock by proceeding with another strip as soon as the last strip was complete.

It may here be remarked that except where there is a definite small hole that can be literally caulked, this stoppage of leaks could not be accomplished against a head of water or by trying to force grout down behind the leak while the water is kept down inside the excavation ; but is accomplished by enclosing the leak by a pipe, freely drained until its cement connection with the surrounding concrete has set. The drainage tube is then closed and the water allowed to find its own level in the caisson tube. Then and only then can cement be forced into the leak

through a small pipe inside the main pipe, and this must have time to set before the tube with the equilibrating column of water can be removed.

Sometimes in rock or other impervious medium a small spring or even soakage occurs, whose hydrostatic head cannot be reached within any reasonable height, and it has been found that the most economical and probably the most efficient method of dealing with such cases is to provide a permanent drainage tube and gutter to lead the water to the drainage pump sump.

On the 25th of January, 1898, Mr. O'Connor again wrote to Mr. Napier Bell, and points out that they are dredging sand at the site he proposed for the dock at Rous Head, hitherto supposed to be rock. He proceeds :—

" This, I think, shows how delusive it would be to suppose that an excavation for dock site at that place would be entirely in rock, and bears out what I always believed to be the case, that there are large fissures in this rock filled with sand, through which the water would come when we came to excavate the dock site, just as freely as through the sand at site proposed near railway bridge, and that being so, I cannot see where the advantage would come in of going to the extra expense of dredging dock site mostly through rock, as compared with the cost of dredging it where it is all sand."

Mr. Napier Bell, replying to Mr. O'Connor on February 21st, 1898, states, *inter alia*, that he still believed in the safety of the Rous Head site, *or* the south side above the railway bridge. He also remarked :—

" . . . . . Apart from my natural fear for recommending a foundation in 100 ft. of sand, I say that where there was any choice every engineer would choose the rock foundation in preference, and only if there was no choice would one tackle the sand. In the sand you must dredge out the required opening, leaving the water undisturbed ; then drive close sheet piling 30 ft. long without joint round and enclosing the entire structure ; pumping well caisson chamber, all enclosed ; then lay under water the entire bottom with thick concrete, and such concrete laid under water is poor stuff usually ; and then start to pump and during the pumping you must wall, strut and caulk the piling. When the pumping has lowered the water 10 ft. or so *the sand will pour* up between the piles and the rough concrete, *undermining* and cracking it, and through the cracks *more sand will flow up* with the water rising from the bottom and undermining the floor still more. .. . ."

Both authorities distinctly saw these points, with this difference, that while Mr. Napier Bell hoped from the hard nodules met in boring that the limestone bore some resemblance to the rock ordinarily called

by that name, and would consequently prove reasonably staunch, Mr. O'Connor distinctly saw that the rock would prove no easier to deal with than would a bed of pure sand 100 feet deep ; in fact, he points out that the greater ease with which sand could be dredged would turn the balance in favor of the sand site. And the ridiculously low figure (compared to rock) at which sand can be dredged allowed, as will be seen subsequently, a very much safer not to say an absolutely safe method to be employed when adapting Mr. Napier Bell's design to a sand site. On the following clauses hang, therefore, for good or ill the whole history of the Fremantle dock, for they apply to any and all known sites in the immediate neighborhood of Fremantle :—

Mr. O'Connor, January 25th, 1898 :—" This, I think, shows how delusive it would be to suppose that an excavation for dock site at that place (Rous Head) would be entirely in rock, and bears out what I always believed to be the case, that there are large fissures in this rock, filled with sand, through which the water would come when we came to excavate the dock site just as freely as through the sand at site proposed near railway bridge."

Mr. Napier Bell, February 21st, 1898 :—" When the pumping has lowered the water 10 ft. or so *the sand will pour up* between the piles and the rough concrete, *undermining and cracking it,* and through the cracks *more sand will flow up with the water rising from the bottom undermining the floor still more.*"*

During the following eleven and a-half years, while the author was interested in the Fremantle dock in its various phases, proposed positions, and vicissitudes, these truths which thoroughly conformed with his own experience were never lost sight of, viz. :—

1st. That the water must remain undisturbed and quiescent during the deposition of the concrete shell ;

2nd. That no pumping should be attempted until the outer shell was complete.

About this time Mr. Thompson instructed the author to amend Mr. Napier Bell's plans to suit the sand foundations below the railway bridge. This he proceeded to do (the late Mr. Frank Shenton acting as assistant) ; at the same time he pointed out that the dock designed by Mr. Napier Bell would be too small for the ships of the future.

The adaptation involved some extensive alterations, due to the porous nature of the strata. The pumping wells were grouped instead of distinct, to allow of being laid in the water as steel tubes protected outside and inside with cement concrete. The sliding caisson was

*This portion of Mr. Napier Bell's letter was meant to refer to the site below the Bridge, but may in conjunction with Mr. O'Connor's letter be used as advice as to how the sand would be pumped up at Rous Head, leaving caves in its stead.

replaced by a ship caisson, to save the walling involved in the caisson chamber, with its adherent difficulty its place being taken by a timber jetty berth. Also a leading wharf was substituted for dolphins, probably for the first time in the history of docks.

But the point of greatest interest in this dock was the proposed method of construction, the method of proceedure being—

1st. To dredge the site, forming a bank round three sides of it to ensure tranquil water.

2nd. An artificial bottom to be formed of clay dredged from Perth Water and transported in barges and rammed in position.

The cheapness of sand dredging permitted this luxury, which while giving weight in a much cheaper form than concrete would also furnish a watertight medium, for, as those of you who have much experience of concrete know, waterproofness is not among its strong points. Moreover, this clay permitted a poor concrete to be used where it was only needed for filling or foundation purposes, as for instance under the haunches of the invert.

3rd. The driving of piles to carry the working stage and traveller, where the mixing tables, etc., were situated and from which the depositing flume was to depend. These stages were to be numbered like twin scales, the traveller also being numbered like a scale, and also the flume, so that the exact position of the concrete deposited would always be known.

Sheet piling supported by the staging jetties was also to surround the dock. It was, moreover, intended to screen off with canvas the portion of the dock where the flume was depositing concrete. Canvas was also to be used over the floor to effectively separate the concrete and clay.

The reasons for adopting the tapered flume were—(1st) to prevent the concrete from coming in contact with the water until laid, and then only on its surface, and (2nd) to provide a column of concrete perhaps fifty feet high for pressure purposes, ensuring a compact and dense concrete.

The flume was to be of wood, be square in section, enlarging as it went down, the lower part having adjustable doors to permit of the concrete being left behind undisturbed as the flume advanced. A cheap temporary bottom would be used any time operations were suspended for any time, because the flume would have to be partially filled before touching the water, and then filled as it went down. When deposition

was started the temporary bottom would be abandoned and as the flume was made to advance it would be fed from above so that it would always remain approximately full.

After laying the outer shell of the floor, the outer shell of the walls would be laid in like manner, the sheet piling acting as a backing and as successive layers of concrete rose inside, clay would be deposited outside, backed by quarry refuse; thus equilibrium would always be maintained instead of heavy and expensive shoring, and whenever possible the sheet piling would be withdrawn altogether to allow of the clay pressing against the concrete.

Finally, when the outer shell had been completed it was the intention to load the partially finished dock with quarry spalls and sand and proceed as at Glasgow.

All these processes may be much more readily gathered from the sketch plans shown by the lantern.

This proposal not only met with the approval of Mr. Thompson and Mr. O'Connor, but Messrs. Coode, Son & Matthews, in their letter to Mr. O'Connor dated the 29th June, 1898, approved of the method sketched out in his letter of the 23rd of May for building the dock below the railway bridge, and were just coming to the same conclusion, and suggest surrounding the whole site with a puddle wall contained between double sheet piling. They further point out that the least depth of water on the sill should not be less than 30 ft. to deal with large men-of-war.

They also point out that the difficulty previously mentioned in connection with the docking of floating docks has been overcome by Messrs. Clarke and Stanfield's invention of a self-docking dock.

In 1898 an English Company offered to equip and work a floating dock and the Government slip and workshops if the Government would dredge a berth for the dock and provide a berth for ships under repair while afloat, and also land for workshops, etc. The promoters suggested that in view of the lower freights and insurance fees likely to accrue owing to docking facilities being available, that the Government should subsidise the capital of the company for a period of not less than ten years at 5 per cent. Mr. Royce, then Resident Engineer for the Fremantle harbor works, reported on this proposal and made some very interesting comparisons between floating and masonry graving docks.

On the 20th March, 1901, Mr. O'Connor points out that if it is necessary to adopt a proposal to carry the north wharf right up to the bridge, the proposed dock site below the bridge would have to be abandoned and the dock and slip put elsewhere—probably further up the river. He shortly afterwards proposed a conference between the Hon. the Minister, the Under-Secretary, Mr. Thompson, Mr. Palmer, the Resident Engineer

for Fremantle Harbor Works, and himself regarding the Fremantle dock. However, Cabinet decided that wharfage should be provided on the north side up to the railway bridge with clear water where Mr. O'Connor thought the dock ought to be.

About the end of November, 1901, the Engineer for Harbors and Rivers (Mr. Thompson) reminded Mr. O'Connor that—

"A port which like Fremantle seems destined to receive the very largest class of vessels should, therefore, I consider, be capable of docking almost any vessel afloat, and the dock would therefore require to be about 750 ft. long with an 85 ft. entrance width, or, should the prospective future be provided for, these dimensions might be 850 ft. long with a 90 ft. entrance."

Permission was obtained to prepare designs for a subdivided dock 850 ft. long with an entrance width of 90 ft. Although 90 ft. would be wide enough for the then immediate future, the author was very anxious for greater width, because it seems unreasonable to suppose that shipowners will continue to be impeded by narrow dock entrances designed for ships of several generations ago, and while docks may readily be lengthened, it is out of the question to widen them. Financial reasons, however, debarring any greater width being authorised, the author had to content himself by making the entrance the prescribed 90 ft. wide, and as no definite position was given he made it 90 ft. wide on the bottom battered to 100 ft. wide at L.W.M., and, thanks to that precaution, the dock as designed would still admit a "Mauretania."

While dealing with the subject of the dimensions of docks it would perhaps be as well to look at some diagrams which the author prepared for the purpose of showing how steadily the dimensions of ships have grown, and by producing the curves the size of ship to expect at any future time, not more than a few years ahead, can be forecast with a reasonable degree of certainty. Only an occasional erratic departing any distance from the curve, such, for instance, as the "Great Eastern," which was nearly as far in advance of her time as her designer, Brunel, was beyond the ordinary engineer of his day in the matter of scientific knowledge.

Another of the diagrams, showing the ratio of beam to length, shows that pretty well all the Atlantic record-breakers have been wide vessels, in spite of the attempts made to gain speed at the expense of beam.

Finding that narrow ships did not give a steady platfrom for gun practice, Sir William White, experimenting on behalf of the Admiralty, found out that no increase of power was necessary to drive a ship with a beam up to one-sixth of her length; in fact, in a rough sea probably less power would propel a vessel of that beam than a narrower ship.

The result is that the "Dreadnought" was launched with a beam of one-sixth of her length. And this takes us back to one of the earliest records of ship building, an entry very similar to those now found in Lloyds' register being written, viz., length 300 cubits, breadth 50 cubits, depth 30 cubits.

Judge of the increased carrying power, not to mention comfort to the passengers, if the 600 ft. liner of to-day were 100 ft. wide instead of only 50 to 60 ft., according to the dock entrances at her ports of call. Is it any wonder that the "Lusitania" and "Mauretania" increased their beam to 88 ft. as against the 68 ft. of the Cunard company's previous greatest effort? And is it not to be expected that the 900 ft. liner of the future will have a beam of 150 ft., with the accompanying stability—and demand docks to suit? Why should ship owners be compelled to build a ship 800 ft. long to carry no more than a ship 600 ft. long could carry with her existing engines, were the dock entrances only made wide enough to receive a reasonably wide ship?

History does not relate how it happened, but in September, 1902, Mr. Leslie, in proposing the removal of the bridges, showed his proposal for placing the dock and slip in Rocky Bay in a position now occupied by a sand bank, as shown on the diagram. This sketch of Mr. Leslie's demands more than passing notice, and shows the benefit of many councillors.

It will be noticed that the dock has two entrances, one at each end. Now, a good many docks have been designed so that they could be used for dry docks when required, such as those at Tilbury, but probably never before had a graving dock designed for that purpose only had a double entrance, and the advantage is so evident for a large subdivided dock, in that it allows either end to be used without disturbing the vessel in the other as independently as if they were two distinct docks, that the author adopted the double end for all designs of a graving dock for Fremantle got out for various positions, with perhaps one exception, that being a one-ended one stuck in the corner of Rocky Bay, at the special request of Mr. Dillon Bell.

In a report dated October, 1902, Mr. Palmer recommended a floating dock to be placed in Rocky Bay.

In 1903 the Premier invited Mr. Keele, the Engineer for Harbors and Rivers employed by the Government of New South Wales, and Mr. Napier Bell to confer with the Engineer-in-Chief for Western Australia concerning the dock site. Mr. Napier Bell was too ill to leave New Zealand; so Mr. Keele came over by himself and prepared plans for a naval station in Freshwater Bay, with a dock at Point Walter, and a commercial dock at Butler's Hump.

Of Mr. Keele's visit the author has little personal knowledge, being absent at the time, but Mr. Keele's reports are interesting, the plan he prepared being screened for your benefit.

Among the dock designs for Fremantle for which the author prepared plans and estimates probably the most noteworthy were those at Point Brown and Rocky Bay, under similar conditions to those below the railway bridge preferred by Mr. O'Connor.

Mr. Rolland also prepared a sketch plan and estimate for the Rocky Bay site, which at one time was the approved dock site. Mr. Rolland's proposed method of procedure was to mould large blocks of concrete on land, approximating to the radial blocks of an arch, fill the joints with broken stone grouted with cement forced through a pipe leading to the bottom level of the blocks, the whole being laid on a levelled bed of concrete put down with a flume and levelled by an H girder, the sides to be built in like manner ; in fact, slabs the full height might be used for the sides if suitable precautions were taken.

Two other alternative proposals were also put forward by the author, not only with a view to providing a dock site below the bridges, but with the further object in view of providing facilities that would outweigh the high cost of wages here compared to those paid at Singapore or elsewhere.

In all floating docks besides the risk of straining or even wrecking the ship, and in many graving docks with shallow entrances ships have to practically strip before entering, cargo, coal and removable heavy gear being all landed, the ship then proceeding to some out-of-the-way corner there to be repaired, painted or scraped, as the case might require.

Now, at certain ports with high tides ships lie on the bottom or even on the gridiron alongside the quay when the tide is out, cargo and passengers going to and from the ship without hindrance ; and it struck the author that if Fremantle could give ships advantages not to be obtained elsewhere, by placing the dock in such a position that the ship could load or unload cargo and be painted or scraped or have ordinary repairs done at the same time, thus saving the loss of time usual to docking, and more than compensating for the high wages paid in Australia compared to England or Eastern countries, and by providing deep water on the keel blocks and entrance, ships could dock with their full cargo and equipment on board, thus saving the expense of unloading and reloading their cargo, coal, etc.

By placing the one side of the dock on the alignment of Victoria Quay extension close to Arthur's Head, the wharf acting as a leading wharf so that ships could berth right up to the dock entrance when required, the other end of the dock opening out towards the deep sea jetty through the present South Mole, a caisson berth and leading jetty screening the

gate from heavy waves, the south side of the leading jetty also acting as a repair berth for ships afloat, the diagram probably making the matter more intelligible than mere words. It will also be seen that the ordinary electric cranes could proceed along the wharf for use at the dock, or conversely. The dock was to be 910 ft. long by 100 ft. entrance, 33 ft. on side, subdivided, the cost without workshops or cranes being £210,000.

The other position was that recommended in the early days by the late Captain Russell, R.N. Here the slip has been built, the excavation for the dock dredged, to designs and plans prepared by the author, Mr. Carlin being in charge of the dredging and slip, the latter being a copy of the old slip.

Here the workshops were designed to be on an artificial island built upon the part of the old rock bar known as The Knuckle, originally left for a wave-breaker, thus always leaving one side of the dock free so that one side of the ship could be in the commercial harbor while the whole ship was in hospital. Access to the workshops from the land side would be over the caisson gates and also by a subway under the central caisson seat, while on the water side a deep-water repair wharf was to have been built, where ships could lie and come under the 150-ton crane if required.

It was this last site that Sir Whately Eliot came out to inspect. He quite grasped the porousness of the strata, but was quite confident that the methods proposed would prove successful, although he preferred the diving bell to the flume. He liked the clay envelope shown in the design for the site below the bridge, but had to abandon it finally on account of the cost of dredging much extra rock and the danger of the dock floating up if clay were substituted for the outer two feet of the concrete shell.

A wooden floor, shown in all designs since 1898, was, after some discussion, and in deference to a wish by Mr. Thompson, left out. Sir Whately Eliot also thought it might prove troublesome when jacking up large plates, and he was not familiar with the wooden floors at Tilbury and Nova Scotia, which were said to have proved so satisfactory and from which it had been copied ; he considered, moreover, that in a climate like this the question of a wet floor was not of the same moment as in Nova Scotia.

The section, pumps, caissons, workshops, cranes, keelblocks, windlasses, bollards, mooring rings, and all other details met with his approval, and he expressed himself as highly pleased with Mr. Thompson's proposal to use a diving bell somewhat similar to that used by Mr. Stoney in Dublin, its method of employ being to set up the frames for the concrete on barges, pick one up and lower it into position and then lower the bell over it. When the first frame had been filled the bell would be raised sufficiently to clear the frame moved over the next one already lowered in position

and let down, the operation being repeated continuously. After the concrete had had time to set divers would open the frames, which would then be removed by a crane and put together ready for another block, the bell returning over the blocks already laid to fill in the joints, which operation would be conducted by lowering a sort of canvas band filled with concrete, as it descended between two blocks until the joint was full to the top, and then dropping the ends of the band and feeding concrete on to the fresh concrete continuously so that the first deposited flowed out, only the outer surface ever coming in contact with the water, and that always the same surface.

The estimate for the first instalment of the dock at Rous Head—length 592 ft. on floor, 610 ft. at coping—was £285,000, the entrance width being 100 ft. and the depth on the sill at L.W.M. 34 ft.; depth on keel blocks, 32 ft.; length when complete, 910 ft. between caissions.

Sir Whately Eliot gave the following replies to questions asked by the late Mr. Price, then Minister for Works:—

> "Taking everything into consideration, I consider Rous Head the best site; if the railway were on the south side I should not consider any site more suitable."
>
> "I would have selected this site if the river were open."

As already hinted, every conceivable method had been considered for building this dock—from churning out wall trenches to driving sheet piling or churning out a puddle trench to surround the whole area, and this method was very tempting, but the author did not think the underlying clay beds sufficiently thick or continuous to warrant the risk, believing that water would pour up from the bottom in such quantities that no concrete could be laid in the dry. Consequently, as already stated, it had been determined to build the outer concrete shell either with the aid of a flume or diving bell. That Sir Whately Eliot was thoroughly in accord with this decision is proved by the following extracts from his report:—

". . . . This rock, however, is of such a porous nature that it cannot be relied on for excluding water, especially on the harbor side, where it has been excavated to form a deep channel, so that when the excavation for the dock is taken out there will be left a wall of rock very porous in nature, and less than 200 ft. wide. Water also would certainly percolate through the rock at the bottom in such quantities as to render its reduction by pumping almost if not quite impracticable. . . .

"Under these circumstances any attempt to exclude water from the site by a cofferdam in the usual manner would probably end in failure, and whether it succeeded or not would be very costly; other means, therefore, must be adopted for the construction, as explained hereafter . . .

" . . . . . The construction of the dock is quite practicable ; it is a work, however, which will present difficulties, and will require the greatest possible care in construction—but the means proposed to be adopted, and explained later on, will considerably lessen the difficulties and minimise the risk of constructing a work of this nature under water. . . . .

" I recommend that as the nature of the ground does not admit of excluding water from the site by means of a cofferdam, the sand and rock be first removed by dredging. . . . . The bottom should be then levelled and prepared for the deposit of concrete by means of a diving bell provided with a double shaft and fitted with air locks by which men and such material as concrete, etc., may obtain access to the interior of the bell without removing it from its position.

Someone having proposed to return to the method of depositing the concrete by means of a skip in lieu of per bell, the author, who did not think high-class concrete could be laid by skip, wrote to consult Sir Whately Eliot on August 2nd, 1909, as to an alternative means. The following extract from the letter explains itself :—

" I have suggested as an alternative cutting blocks of granite by plug and feather as large as our cranes would allow, but certainly not under 6 ft. x 4 ft. x 3 ft. and probably double that size, say, 7 ft. 5 in. x 5 ft. x 4 ft., laying them on a bed of 2 to 1 cement mortar about 6 in. apart and then forcing 2 to 1 cement mortar through a pipe to fill up the spaces between them. By thus covering the bottom with a layer whose long axis was parallel to that of the dock, each row breaking joint with the next and covering it with a second layer, breaking joint everywhere with the lower, the stones sitting on their narrow side in both layers, the sides being built up with similar stones on the flat to above water level and all breaking joint, I think the dock would be pretty water-tight when pumped out for the purpose of finishing off the inside in the dry.

" The inland granite cuts beautifully : it is not all cracked and fissured nor flinty like that in the Darling Ranges. When walling in big rocks, *i.e.*, putting a gutter round them to collect water for railway purposes, I used to cut slabs about 60 to 70 ft. long by about 4 ft. 6 in. wide and 12 to 18 in. thick for about 30s., the cutting of them into lengths that could be handled being an extra, depending on the distance to be transported ; if used where cut, I have turned up as much as 22 lin. ft. in one piece. The principal reason for the excessive cheapness being that the great variations in temperature cause a shell to flake off the rock, which can expand and contract above the mass. For large quantities of stone one would have to rely on the solid rock."

The reply to this must have been mislaid, there being no sign of it among the author's papers.

The means of cementing the stones together is only touched upon in the above letter, but the method would have been after a few rows of stones had been laid to block the outer ends of all joints by sand bags or other approved means, lower the grouting pipe to the bottom, fill it with 2 to 1 cement mortar, then raise the pipe two or three inches and force in mortar until it had risen up level with the top of the stones, and then withdraw the pipe and renew the process again and again ; or fill the joints with broken stone and force grout instead of mortar, as described above.

The following information, together with plan of sections of dock and pump well, was supplied to pump makers to allow them to tender for pumps, the design being left to maker.

Capacity of Pumps.

The dock when completed will be about 910 ft. long (between caissons) and will contain, when filled to H.W.M., about 25,000,000 gallons of water.

The pumping plant, which it is proposed to place in a well be cope level, must be capable of discharging the above quantity in 4 hours.

The floor level of the dock on the centre line will be 36 ft. below low-water mark, and at the sides 6 in. lower.

The section proposed for immediate construction will be 560 ft long between caissons, and capable of being divided into 2 compartments, 210 ft. and 330 ft. long respectively, by an intermediate caisson.

The capacity of section to be built immediately, when filled to H.W.M., will be about 16,500,000 gallons. The pumps shall be designed as three equal and similar units, so that if only two such were ordered now, they would be capable together of pumping the present section in 4 hours, and that the addition of one other such unit when the whole dock should be completed would render the complete plant capable of pumping the full dock (capacity 25,000,000 gallons) in 4 hours.

A smaller drainage pump to be also supplied.

Discussion.

Mr. J. W. Henderson said all that Mr. Shields has quoted *re* tonnage passing through a port to necessitate a dock for repairing ships' hulls, etc., is true ; in fact, Fremantle is situated in a geographical position

that makes the situation more acute. The first site proposed is shown on the model at the Museum, and when attempts were made to put down a shaft to a depth of about 14 ft. was attained with timbering. When iron cylinders were used, a depth of 27 ft. with Pulsometer pumps was attained. Mr. Napier Bell was my informant about this, as I was his mechanical assistant at the time, and advised him to put the shaft down. The borings for the Rous Head site showed a nasty foundation, and late developments have shown that it was unwise to attempt a dry dock there. I pointed this out to Mr. Napier Bell, and as far as I recollect his reply was "It is better than a quick-sand." With reference to floating docks, Mr. Shields is in error. In 1890 and 1891 I was in Fremantle and foresaw the difficulties, and on return to England obtained information and submitted it to the Public Works Department. I am still in favor of a floating dock for Fremantle. I have seen them, been on them, and while their upkeep is more and their life shorter, they are to be preferred to a dock that has not eventuated, and accidents happen to even the best graving docks that have been constructed.

Mr. J. F. Ramsbotham did not consider that tonnage has any connection with the number of graving docks required. One might say that the Suez Canal ought to be composed of graving docks. And another point, graving docks are usually in places where there are the established industries of ship-building and also where repairs are carried on—generally at terminal ports. A letter from Mr. Napier Bell to Mr. O'Connor, suggesting putting a bank of clay round the whole site, say 7 or 8 feet in depth, to keep the surface water on the top of the reef away and taking the walls out in trenches all round, and then taking the floor out in sections, also in trenches, and I am bound to say, in my opinion, if that had been done you would have had a graving dock at Fremantle. In the work I have been engaged on we have had the water right up against us—a head of 54 feet of it—and I had got lower than Mr. Napier Bell. It was a much smaller dock at that time and the depth he (Mr. Napier Bell) was going to found on was 37 feet below low water mark. In regard to the suggested dredger scheme: if we are going to dredge the body of the dock out and then concrete under water before starting, one must have absolutely no doubt about the bottom. The author suggests putting clay on the bottom and ramming it. Personally, I have done a good deal of work with clay, and I know this, that if you ram clay you turn it into mud—the portions of sand, etc., in it become disintegrated and it becomes mud. Then, apparently, that having been done, concreting was going to be started with a flume. When your concrete goes into mud, the specific gravity of the concrete is greater than mud and the mud will come up and mix with the concrete and you will have an unsatisfactory mixture. Again, looking at pressures, the safe intensity of pressure on natural foundations has been determined as follows:—

(1) On hard rock, 9 to 10 tons per square foot ;

(2) On soft rock and hard clay, 2 to 3 tons per square foot ;

(3) On sand and gravel, $1\frac{1}{2}$ to 2 tons per square foot ;

(4) On compact earth, 1 to $1\frac{1}{2}$ tons per square foot ;

(5) On soft uncertain ground, $\frac{1}{2}$ ton per square foot.

Several engineering features manifested themselves during the construction of the Brocklebank Graving Dock, Liverpool, which I carried out under my late chief, Mr. Anthony G. Lyster. In three different places it was necessary to excavate 80 ft. in order to get a safe foundation, needless to say at considerable expense ; but in work of this character no gratuitous risks must be taken—if they are taken and disaster follows the amount involved in getting a safe foundation is very small in comparison with the amount entailed by the disaster. To my mind there are three points an engineer must consider :—

(1) Can the work be done ?

(2) What will it cost ?

(3) How long will it take ?

Then, further, in constructing a graving dock there are two cardinal points. In almost all excavations water is encountered, and a decision must be arrived at as to whether it is going to be possible to allow such water to weep away in relief or necessary to block it out, on account of there being too much water for the drainage pump. In the event of the latter concrete *en masse* is necessary, or a floor fortified with steel capable of withstanding the hydrostatic pressure from below. It was my intention (without any option) to have done this with the graving dock at Rous Head. In the case of the Belfast graving dock, which I saw when it was under construction, the floor was, I believe, 20 feet thick and a 5-ring blue brick arch in the concrete in addition, which was carried up the back of the walls. The issues are quite clear and it is advisable to realise them before starting. The next consideration is, what pressure will arise when a steamer is on the keel blocks ? An Atlantic mail boat has a pressure of 80 tons to the running foot ; with keel blocks at 30″ centres, this amounts to 200 tons per block, or, say, 175 tons for an ordinary type of mail boat. In the case of a damaged keel which has taken up an arch formation for considerably over 100 feet, these pressures may be considerably increased and all possible contingencies must be considered. In the case of the pressures on the toe of your wall, for a wall similar to the Fremantle graving dock, a pressure of 5 tons to the square foot arises, and unless the ground is suitable unquestionably trouble may be expected. For a wet dock 4.4 tons per square foot arises and the possibility of the wall sliding must not be forgotten. Then the author goes on and talks about putting in a shell. When you are putting in a shell to withstand the

ultimate pressures, the dock on being unwatered for the first time gets the ultimate pressure straight away. A shell is very little use unless it is so constructed as to be able to withstand the ultimate pressures. I am not quite clear about the method adopted at Glasgow, and perhaps the author would tell us how they did proceed, at the same time giving us the depth of water on the sill. And then going on further, I see a wooden floor was discussed. I have seen a drawing of it—an arch somewhere about 6 feet thick made under water with joists on it and then a 2″ floor. There was one other point I saw about dredging out and making concrete blocks, then putting a skim of concrete on the bottom and placing on it the concrete blocks. My remarks about pressures apply in the same extent to that method—a doubtful method, very doubtful; it is hard to build a big concrete arch in the dry, to build such under 50 ft. of water borders on the absurd.

Mr. A. J. Hillman said: In reference to the shipping tonnage at the various ports referred to by the author, I think it would be advisable to render that a little more clear by stating whether the tonnage is tons of shipping or the tonnage of shipping inwards and outwards combined, as is shown in the case of Fremantle, and whether it is gross tonnage or nett tonnage. The figures for Fremantle are up to date in that matter of 4½ millions, whereas the figures for the other ports are evidently four years old. I think four years ago Fremantle was about 2½ millions. In joining new work on to work which is two or three days old it has always been my practice to scabble the existing work and coat it thoroughly before bringing fresh work on it, and I think that is the only method by which a continuous bond and a continuous body of concrete can be formed, and the only way to prevent vertical seams or even horizontal ones in a work That is my method, and which has always been my practice in the dry, but to carry out similar methods under 40 or 50 feet of water is impracticable, and I think that a dock floor would be exceedingly porous when it came to be under water for the first time. A dock site cannot be dredged like cutting cheese with a knife, and a very uneven bottom would be the initial result if that is covered by the next proposal—an artificial bottom of clay, etc. What method of ramming would the author propose by which to ram clay dredged from Perth water 30 feet under water? I picture up a "pug" of about the consistency of pea-soup in which any system of ramming would generate into; any system of ramming is to my mind absolutely impracticable.

Mr. J. A. Ridgway said: Nobody will deny that this paper is an extremely interesting one. There are many matters of more than passing interest. In Whittaker's Almanack for 1910, the shipping tonnage of 1908 is given, which is exactly four years ago. This tonnage evidently refers to nett tonnage, which is the usual method of measuring tonnage. The tonnage is divided up into tonnage entered and cleared. According

to Whittaker, in 1908, Southampton, instead of having a tonnage of 3,800,000, as stated in the paper, had a total tonnage of 7,921,000 tons. On the same basis, Newport, instead of 2,700,000 tons, had 3,894,000 tons, and so on. Glasgow, instead of 4,300,000 tons, 5,000,000; Cardiff, instead of 13,200,000 tons, nearly 15,000,000; and Newcastle, including North and South Shields, instead of 9,000,000, 12,489,000 tons. For Melbourne and Sydney the tonnages are given for 1907 and they are respectively 743,246 tons and 1,884,700 tons, instead of 6,500,000 tons and 5,900,000 tons. As regards Fremantle, the author gives the tonnage for 1912, and I have it only here for 1907, but it then approximately amounted to about 1,000,000 tons. That, undoubtedly, is nett tonnage, whereas the author's figures may be in reference to gross tonnage, and I shall be glad if he will enlighten me. Of course, if the tonnage I have given for Melbourne is correct it all the more points to the necessity of having a dock here in Fremantle, when Melbourne, as the author says, has three docks and five slipways. The statement the author makes as regards foreign ports not having so many docks as British is very interesting, and I should be glad if the author could give me the name of the port to which he refers just below as having a 50 feet rise and fall of tide and having only one gridiron. The author states that the idea was to design a dock which would be satisfactory for discharging cargo and cleaning the ship's bottom at the same time. The majority of shipowners are, I think, always against putting their ships into dock in a loaded condition, for it is clearly advisable to empty your ship so as to do away with any tendency to strain. When men are working underneath it is hardly a good proposition to discharge cargo at the same time. In Liverpool I can only call to mind one ship which discharged cargo in the graving dock. The author's reference to floating docks is all too short. It would be interesting if he would briefly give reasons as to why the floating dock proposition was apparently shelved, and in addition would he state his views as to the respective merits of a dry dock over a floating dock, or *vice versa*.

Mr. W. Leslie said there are a few points, some of which have been mentioned, that in my opinion ought to be made clear when the paper is revised. Several references have been made to the tonnage and it is not clear whether the tonnage is annual or not. I agree with Mr. Ramsbotham, it depends entirely on the status of the port as to the number of docks required. As pointed out, ship owners are very loth to put the ships into dock when they are loaded, and in every occasion where it has been done it has caused considerable extra expense and also in the insurance. A port of call like Fremantle is not to be treated in the same manner as a terminal port, or in the same way as a port where there are facilities given for repairs being carried out to ships when they call at the port. The author refers to the difficulty to docking a ship when the ship is at right-angles to the stream, but I think exaggerates it. We

know that a great many docks are placed in rivers at home where there is probably 10 or 15 feet rise and fall, and taking one ship out and putting one in on the top of a tide. There is a great deal more work done in more current than we are ever likely to get in the estuary of the Swan; this difficulty may be got over by tugs. Timber docks were, I think, first built in America, and they were known as the Simpson docks. I think there has never been an instance yet of a timber dock floating, the reason being that the sloping sides—they were very wide batter at the bottom—were all very deeply piled and the fastenings made to the piles so that really the dock was well anchored down. There was one burnt, I believe, but I think, although it was constructed of timber, we have not had an example of a Simpson dock floating yet. Of course, repairs to the timber docks are very much higher than the other docks, to which the cheap construction lends itself. There is one thing that the paper does make clear, and that is the strata at Fremantle appears to be perfectly well understood in Mr. O'Connor's time. I think Mr. O'Connor, from the information which he had before him, was remarkably correct in regard to the strata at Fremantle; a good deal of information in regard to it has been obtained since Mr. O'Connor's time, and, of course, it is all the more credit to him to be able to foresee that. The author must have had a good deal of trouble in regard to the way he proposed to put up a working stage and deposit his concrete down there. It would have been of value to have had more particulars as to that, the moving of that flume and the opening the door—the moving of the flume along the bottom. It does not appear to me, however, to be practicable. The history of the No. 4 graving dock in the Brookland Navy Yard seems something like Fremantle. In the first instance a contract was let for the construction of a dock 563 feet long and about 100 feet wide. After fifteen months' work the contractor decided not to proceed further. A little later the Government again called for tenders for the dock, 620 feet long. A company got it and decided they would adopt a method somewhat similar to what was employed at Fremantle. That was the two lines of steel sheet piling, and endeavored to get the site dry in that way. They worked on it also fifteen months and failed, and for a second time the work was abandoned. The Government found it necessary to have a dock. Ships were calling for dock accommodation, and their own cruisers made it necessary to lengthen the dock again. Tenders were called again, and the length increased to 723 feet and the width I think 100 or 120 feet, but it was a success the third time. The contractor took one of the ways of which the author has not taken into account. That is, he sunk a series of caissons right round the outside of his dock—they were a little distance apart; where they were joined he left a half-moon so that the concrete could afterwards be filled in between each of the casoons right round. The Government Engineer went into the matter with the contractor in regard to putting in a reinforced bottom

instead of the ordinary concrete bottom. It saved some 10 or 15 feet in the deptn of the concrete in the bottom, but the difficulty there was that the strata was quicksand and loose sand, gravel and boulders down to 110 feet below the surface, so that each of these casoons sank down to solid rock 110 feet and the work was at length completed. There are one or two things in the proposed method of construction of the dock that the author sets out that rather puzzle me. One of them I refer particularly to—a suggestion which he made to Sir Whately Eliot, dated 2nd August. He refers to the adoption of a cut granite bottom. I quarried a good deal of these blocks in the hills, and I think one cannot go very far into that before it becomes very expensive. It is quite true they are lying in beds 12 and 18 inches and up to 3 feet thick, but when you proceed to get a large quantity of stone from anything you soon get into the solid granite, and then it becomes expensive—especially with our high cost of labor. The author says he would lay them in the bottom of the dock. I take it on a bed of cement and grout them in between, but what troubles me is how it is proposed to get the mortar down there, and I thought if one could get the stones down into the bottom for a foundation that they could get the concrete in all right.

Mr. Shields, in reply, said Mr. Henderson is quite correct in referring to the difficulties in sinking that shaft in Mr. Napier Bell's time, and there was also the same difficulty in sinking the shaft above the bridge. The water was pumped out and as the water was pumped out the sand rose in the shaft and they were not getting any deeper. If the water had been left in the shaft and an ordinary sand pump used it could have been sunk to any depth required without any trouble. As to the information on the floating dock that Mr. Henderson mentions, they did not act in conjunction—they both acted independently. There is a great deal about floating docks. Mr. Henderson also says that a floating dock would have been better than a graving dock. It is not a substitute—it has not got the stability. The stability of the ship has to be taken into account when you put a ship on the floating dock; and it has been said there have been accidents in graving docks, but there also have been accidents in floating docks. There have been accidents—where a ship launched herself off a floating dock, and the Havana floating dock broke in two. Coming to Mr. Ramsbotham's remarks: The tonnage has no connection with graving docks. Of course, there is a certain amount of reason in that, and where a port receives a large amount of shipping it ought to have graving docks in comparison with that shipping. In England, where a ship can go to an adjoining port a few miles away, it is not so important as here, where we are 2,000 miles from one. A ship coming all that distance is liable to accident. Mr. Ramsbotham said I was inaccurate in saying Mr. Dillon Bell proposed the first wooden dock at Rous Head, instead of Arthur's Head. I do not think I was. Mr. Dillon Bell proposed one for each side on two consecutive days. With reference

to the few notes in Mr. Napier Bell's letter read out by Mr. Ramsbotham, he refers first to the site at Rous Head and then to the site below the bridge, or conversely, but I thought it was quite clear from his letter which he referred to. In one he refers to the porous rock, the limestone rock interbedded with limestone rock and sand. In the other he refers to nothing but sand. And you would have to put sheet piling down, and if you went to lower the water 10 feet the sand would come up. There is no doubt there would be great difficulty. My idea is not to lower the water in either case—there was a shell of concrete, and the reason for that is that those who have had experience of this rock, say it would be exactly the same at the bridges. The rock at Arthur's Head and the rock above the bridges is not one bit better than the rock at Rous Head or Rocky Bay. It is all as porous as a sponge. Mr. Napier Bell thought there was hard limestone at the bottom, as you see in the papers; Mr. O'Connor disagreed with that. Mr. O'Connor maintained that the rock was absolutely porous. The next item is the rammed clay becoming mud and rising and becoming mixed with the concrete. I do not know whether Mr. Ramsbotham referred to the mud in Perth Water and clay. There is an outcrop of clay in Pier Street, and also in some Government land at the back of the Technical School. It appears to be a very tough clay and it has water running on it. If it was found to run it would have to be replaced by some better class of clay. A good deal was dredged up in Perth Water and it came out of the water perfectly tough. He referred to the weight on foundations—3 tons on clay and 2½ tons on coral in the United States. I do not think we can put that much weight on the bottom. If you take a 50 feet column of concrete, what would it weigh? I should say, allowing about 16 feet to the ton, it would go a little over 3 tons for the total column from top to bottom, and against that you would have the upward thrust of the water, which would relieve it by fully a third. There would be no sliding of the toe, because the invert bottom would prevent the toe sliding in. You would have the higher ground inside and the clay and the mud and you have to allow for all the water above water level. In a wet dock you have nothing to prevent your toe sliding out—in a graving dock you have the whole of the floor which prevents the bottom sliding across; it has an equal thrust on the other side of the wall. A warship is actually heavier than a ship like the "Lusitania," because she has a shorter level of keel. When the ship comes on the floor, as a matter of fact if the dock were not held down by friction it would float it. When the water was pumped out the dock would float, ship and all. So that it only comes to a matter of distributing the weight of the ship from the keel blocks over the floor. We had steel rails laid in the concrete—that was the actual proposal. I think the concrete itself would have taken it up—it would have spread the pressure. There are two ways of making the shell. If you laid a shell of concrete to be finished in the dry you must either make that shell of

concrete sufficiently thick to resist the water pressure and flotation if it is not held down, or else you must load it. In the case of the Glasgow dock they made quite a thin shell but they loaded it up with spalls or sand inside, and then they excavated in those spalls a narrow trench, that only left a narrow space of floor—I think it was 10 feet. If you take out a little strip as wide as a table right across the dock, a comparatively small thickness of concrete acting as a hidden arch will keep the pressure down, and you could make that piece tight, and, having made that piece tight, make an advance and make the next strip tight, the pressure on this new concrete keeping that down till you get the whole of it in. Mr. Ramsbotham referred to Mr. Rowland's method of laying concrete blocks under water. Of course, laying these under water presented difficulty, as any work under water does. I referred to a dock that was proposed to be put across the South Mole. I explained exactly—I mentioned the price for it. The reason for the excessively cheap price was that we had an offer at that time of a stack of slag from the smelter which I think the Government analyst reported on very favorably for concrete. The proposal was to make long blocks and grout them afterwards. It is exceedingly difficult and the trouble really is to get some feasible method of laying the concrete under water. It has been shown in many cases that the vertical joints can be grouted. I dare say a good many are familiar with the work that Canniple (?) did on the Guernsey structure—he grouted those through a pipe and made good concrete. We tried the same method at Fremantle with great success. We made some very nice blocks and grouted in different ways. You cannot have horizontal joints if you are grouting under water, but you can have them on the slope. Mr. Hillman referred to the table of tonnage at the ports. That was taken from a public file—I think it is from Mr. Palmer's report. It is on one of the public files; some of the men of our Department could tell you which, and at the time, as well as I remember, I compared that with the Fremantle Harbor Trust's report. In reference to the method of ramming with clay under water, the intention was to run it through the flume the same as the concrete. Personally, I think you could ram it if you got the right clay with a flat ram. You would have to force it through the flume. Mr. Leslie mentioned that a wooden dock was never known to float. I consider that they are too porous to float.